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THESIS

USING INCENTIVES
TO
IMPROVE MAINTAINABILITY

by

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December 1984

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Using Incentives
to
Improve Maintainability

by

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I. INTRODUCTION

A. GENERAL

Integrated Logistics Support (ILS) is a concept introduced over two decades ago. In June 1964 the Department of Defense issued its directive which defined ILS as "a composite of the elements necessary to assure the effective and economical support of a system or equipment at all levels of maintenance for it's programmed life cycle." [Ref. 1: p. 2] The general policies of that directive succinctly stated the importance of ILS in the following:

> Development of ILS for a new system shall be initiated concurrently with the performance requirements or at the earliest possible time in the conceptual phase and at the procurement planning phase for commercially available items. The evolution of logistic support, that is, the integration of its elements shall be the result of progressive system analyses of the plan for use and the plan for support and indicated trade-offs between these plans through all phases of the project. [Ref. 2: p. 2]

Integrated Logistics Support is composed of eleven elements: maintainability, reliability, maintenance planning, supply support, support and test equipment, transportation and handling, technical data, personnel and training, and interim support [Ref. 3: p. 10]. It differs from normal logistics concepts in that it involves several different disciplines and that it involves the interaction of all the elements throughout the entire programmed life cycle of the system. The logistics costs of a weapon system comprise about eighty percent of its life cycle cost. However, in the past ILS did not receive the same consideration early in the acquisition process as did the hardware to be used in the system. The importance of ILS cannot be overemphasized in the wake of increasingly complex weapon systems and the staggering expenditures of tax dollars required to purchase and support them. Former Secretary of Defense Harold Brown emphasized that point in Consolidated Guidance when he said of our tactical air forces:

> The costs of buying and operating tactical air forces are taking an increasing share of the defense budget. Their increasing complexity is a significant factor not only in this growth, but also in an increasing difficulty in maintaining the combat readiness of our air crews and their equipment. These trends if continued, could jeopardize our ability to maintain a force that is large enough, that is modern enough, and that is ready enough to carry out our plans. [Ref. 4: p. 29]

To further emphasize the need for more ILS considerations in weapon system acquisition and to outline a program for improving the acquisition process Mr. Frank C. Carlucci, the Deputy Secretary of Defense, issued a memorandum in April 1981 that contained thirty-two initiatives designed to accomplish necessary improvements [Ref. 5]. Mr. Carlucci felt that if these tasks were successfully accomplished, system acquisition would be streamlined and cost savings would result. One of the initiatives specifically required that readiness objectives be established for each weapon's development program and then required that reliability and maintainability be designed into the system. This initiative has been restructured to include key aspects of other of the initiatives, one of which is the use of incentives to motivate the contractor to improve the readiness and support of newly acquired systems [Ref. 6: p. 15].

Incentives are not new to defense contractors but to date have focused primarily on motivating performance, schedule, and cost objectives of the contracting parties [Ref. 7: p. 30]. However, various forms of incentives have recently been used in the area of logistics in an effort to improve the availability of today's systems. To date these incentives have largely been in the form of warranties and have focused on the negative motivational aspects of an incentive [Ref. 7: p. 31]. They have been structured to become effective after the equipment has been fielded rather than in the design phases of the acquisition. A more effective incentive might be to motivate the contractor during the design of the equipment so that improved availability is designed into the system from the start rather than attempting to remedy it after the system is developed. This thesis explores the use of incentives toward that end.

B. OBJECTIVES OF THE RESEARCH

The objectives of the research were: (1) to investigate the concepts, characteristics, and issues involved in the topical areas of incentives and maintainability, (2) to determine if defense contractors could be motivated to improve the maintainability of a system during design, and (3) how that motivation might be accomplished.

C. RESEARCH QUESTIONS

The primary research question was: Can Can incentives be used in Government contracts to improve the maintainability of equipment acquired in the future?

The subsidiary research questions were:

1. What is maintainability?
2. How does maintainability relate to the acquisition of equipment today?
3. What motivates a contractor to do business with the Government today?
4. What are the significant characteristics of contract incentives?
5. What would the objectives of incentives for maintainability be in Department of Defense contracts?

6. What are the current methods used to promote maintainability in Government contracts?
7. How can incentives be used to motivate the contractor to improve maintainability?

D. SCOPE

The main thrust of the study focuses on the element of Integrated Logistics Support known as maintainability and the appropriateness of using incentives with the contractor designing the system in an attempt to improve it. The research focuses primarily on the Government's use of incentives with defense contractors in the procurement of major end items. In addition, research was conducted into the area of incentives with particular attention paid to the most effective incentives from the contractor's point of view. Finally, the study shows how incentives can be used to motivate contractors to improve maintainability during the design phases of the acquisition. The study does not attempt an analysis or the construction of a maintainability model. It does not attempt to evaluate the cost-effectiveness of maintainability nor does it critique current maintainability engineering techniques. The study does suggest possible methods of motivating contractors to improve maintainability in systems under design.

E. METHODOLOGY

In order to answer the primary and subsidiary research questions a combination of research techniques was utilized. The first of these was to use existing data in the literature on maintainability models, maintainability, use of incentives, structure of incentives, and contractor motivation to form the basis of the study. The second research technique involved interviews with Government logistics personnel and defense contractor representatives from companies located primarily in the California area. These contractor personnel included individuals in contracts, engineering, program managers, and other acquisition personnel as would be appropriate for this study. A list of the personnel interviewed appears in Appendix A of this thesis. To permit those interviewed to answer questions freely, all interviews were conducted on the basis of nonattribution. A list of the primary interview questions appears in Appendix B of this thesis.

F. ASSUMPTIONS AND LIMITATIONS

The major assumption in the study is that the reader has some familiarity with the procurement process but not necessarily a professional background in the field. It is further assumed that the reader is aware of the relationship that exists between the defense industry and the Department of Defense.

The major limitations encountered in the study involves the material currently available on the use of incentives in the manner under study. A great deal of material exists that discusses incentives, but most of that material concentrates on the use of incentives to motivate the contractor to stay on schedule or under cost. Only recently have attempts been made to motivate the design contractor to improve any of the elements of support and published material on the effectiveness of those efforts is not yet available.

G. ORGANIZATION OF THE STUDY

The study is organized in the following manner: Chapter II contains a description of the acquisition process, the design process and pertinent definitions. Chapter III is a discussion of the issues concerning maintainability and their role in the acquisition process. Chapter IV contains a discussion of the issues surrounding the use of incentives in defense contracts and a discussion of those factors that motivate defense contractors to do business with the Government. Chapter V discusses the case of the F/A-18 program and the incentive program used to improve the maintainability of that system and provides an analysis of the program's success. Chapter VI provides an analysis of the problems and issues surrounding the use of incentives for maintainability improvement. Chapter VII finishes the study by providing conclusions derived from the research, recommendations on potential future use of incentives to improve the maintainability of new weapon systems, and answers to the research questions.

II. BACKGROUND AND FRAMEWORK

A. MAJOR SYSTEMS ACQUISITION PROCESS

In this chapter the major system acquisition process and the system design process will be discussed and pertinent definitions to be used later in the thesis will be provided. The introduction of a major weapon system is the result of a detailed and systematic decision process. The process begins with the recognition by the Secretary of Defense or one of the DoD component chiefs that a need exists in some mission area [Ref. 8: p. 3]. The mission need can be the result of a perceived or actual change in the current threat, a change in the state of technology, or a change in an assigned mission element. Continuing analyses of assigned missions by the Secretary of Defense, the Joint Chiefs of Staff, and the DoD components establishes the need for the new system. The purpose of the analyses is to identify deficiencies or to identify more effective means of performing assigned missions [Ref. 8: p. 3]. However, before making the decision to acquire a new system, a thorough investigation of alternatives is conducted to ensure that the need cannot be satisfied by a change in tactical or strategic doctrine, the use of existing military or commercial systems, or through the modification and improvement of an existing system [Ref. 8: p. 4]. After the identification of a need is established and acquiring a new weapon system is determined to be the only satisfactory means of satisfying the need, there are two basic requirements to be satisfied for initiation of the acquisition process: the first, is the preparation of a Mission Need Determination (MND) and the second, is the allocation of funds for the system [Ref. 9: p. 10].

The allocation of funds for a new system is quite involved in itself as it is integrated fully into the Planning, Programming, Budgeting System (PPBS) used to develop this nation's budget. Stated briefly, however, to receive funding for a program a Justification for a Major Systems New Start (JMSNS) is submitted with the DOD component's Program Objectives Memorandum (POM) to the Secretary of Defense. The Secretary of Defense then issues a Program Decision Memorandum (PDM) which includes the approval or disapproval of the JMSNS. Approval of the JMSNS authorizes the start of the new system and begins the acquisition process.

There are four major phases in the acquisition process today: Concept Exploration, Demonstration and Validation, Full Scale Development, and Production and Deployment. The phases follow the same general pattern regardless of the acquisition category of the system being acquired. There are four major Acquisition Categories (ACAT) for a new system differentiated primarily by the authority level at which the decision to continue or not to continue the acquisition is made [Ref. 9: pp. 32-34]. The categories are also differentiated by dollar thresholds for research and development costs and production costs for the system. In ACAT I level systems the decision authority rests with the Secretary of Defense for most of the acquisition process. A financial threshold of $200 million for research and development and $1 billion for production is usually considered to be the minimum threshold for an ACAT I system. Most major weapon systems remain in this category. ACAT II programs utilize the service Secretary as the decision authority and utilize a threshold of $100 million for research and development costs and $500 million for production costs. ACAT III and ACAT IV retain decision authority within the DoD component concerned and do not utilize thresholds for research and development or production costs. These categories are differentiated primarily by the effect of the acquired system on existing hardware or mission capabilities. [Ref. 9: p. 34] It should be noted that the Secretary of Defense can retain decision authority regardless of the thresholds involved if the urgency of need and development risk are high or it is a joint program with other nations or between more than one DoD component [Ref. 9: p. 4]. For the purposes of this study the acquisition process described will be that of an ACAT I level system.

The first major phase of the acquisition process is the Concept Exploration Phase. During Concept Exploration many activities take place; among them the appointment of a program manager, the drafting of his charter, the development and refinement of an acquisition strategy, the initiation of studies to arrive at performance, cost, schedule, and supportability estimates, and the development of test and evaluation criteria. The most important activity, however, in this phase is the solicitation from industry, in-house laboratories, and universities for alternative concepts for evaluation as a means of satisfying the mission need. The objective of the Concept Exploration Phase is to select the most promising system concepts to continue into the second phase of the process. Maintainability considerations are in its infancy during Concept Exploration. They are usually stated as a series of general parameters that form the basic maintainability objectives for the system. [Ref. 3: p. 22] Concept Exploration ends with a decision at Milestone I. This decision is made by the Secretary of Defense based upon information provided in the Milestone Review Documentation (MRD) which includes a Systems Concept Paper (SCP) and a Test and Evaluation Master Plan (TEMP). An approval of the MRD at Milestone I concludes the Concept

Exploration Phase and starts the Demonstration and Validation Phase of the acquisition. [Ref. 9: p. 14]

During the Demonstration and Validation Phase the surviving alternatives undergo analyses, hardware fabrication, and test and evaluation to verify that the risks and uncertainties involved in the remaining alternatives are identified and reduced to acceptable levels [Ref. 9: p. 41]. This phase is used to demonstrate that the needed technology is at hand to ensure that only engineering development is required to develop the concept. In addition to verifying the existence of the technology necessary for the system, performance and mission envelopes are defined and trade-off analyses of capabilities versus cost are conducted in order to select the concept for full scale development. During Demonstration and Validation, maintainability parameters are allocated to the lower levels of the system and these parameters begin to become more definite and measurable. The contractors developing the design begin to make their trade-off analyses to test the achievability of the objectives stated. [Ref. 3: p. 22] The objective of the Demonstration and Validation phase is to identify the system concept having the greatest potential for meeting the mission need in a cost effective manner. The conclusion of Demonstration and Validation occurs at Milestone II. At Milestone II the Secretary of Defense reviews the MRD for the system. The MRD is basically the same as that used at Milestone I except that a more detailed Decision Coordi- nating Paper (DCP) is used instead of the SCP. In some cases, the decision authority will require more detail than that present in the DCP and thus require that an Integrated Program Summary (IPS) be submitted also. Approval of the MRD at Milestone II concludes the Demonstration and Validation Phase of the process and authorizes entry into Full Scale Development of the system. [Ref. 9: pp. 41-45]

The Full Scale Development Phase is a period of careful, iterative, and detailed engineering effort [Ref. 9: p. 51]. By this stage in the acquisition process, the alternative concepts have been narrowed down to one or two systems that can satisfy the mission need in a cost effective manner. The objective of this phase is the demonstration and documentation of a cost effective, operationally suitable, reliable and production engineered system that meets the mission need. [Ref. 9: p. 53] During full scale development the producibility of the system will be demonstrated through the establishment of the production lines to be used during the last phase of the process. Also, during this phase the maintainability parameters established earlier and allocated to the system can be tested on the prototypes developed during this phase. By this stage in the system's development the design effort for the maintainability of the system is virtually completed [Ref. 3: p. 23]. The final decision point, Milestone III, requires the same basic documentation as that required in Milestone II, however, in many cases the decision authority for approval at Milestone III has been delegated to the DoD component Secretary [Ref. 9: p. 66]. Milestone III concludes the Full Scale Development Phase and begins the Production and Deployment Phase of the acquisition process.

Those activities designed to produce the system in a cost effective manner and issue it to the inventory describe the Production and Deployment Phase of the acquisition process. This phase will continue until the system is no longer required to fulfill a mission requirement. Although the process consists of four distinct phases, flexibility and concurrency are encouraged where possible to expedite the fielding of the system. Fexibility and concurrency, however, are not to be pursued at the expense of sound management practices. The entire acquisition process is evolutionary in nature beginning with a mission need, evolving into a conceptual idea, then into an engineering prototype, and finally into a mission ready system for the user.

B. THE DESIGN PROCESS

The design process is also evolutionary in nature beginning with an idea and evolving into a physical model of the system. The process begins with a conceptual design which includes feasibility studies directed toward defining a set of useful solutions to the need to be satisfied [Ref. 10: p. 186]. The output from this phase of the design contains a technical baseline for the system, a definition of the systems operational requirements, and the maintenance concept [Ref. 10: p. 186]. This phase of the design process occurs during the Concept Exploration Phase of the acquisition process. The second phase of the design process is the Preliminary System Design. During this phase of the design the baseline configuration identified in the conceptual design is used to identify system level requirements and detailed qualitative and quantitative characteristics [Ref. 10: p. 186]. It is during this phase of the design that trade-off studies, logistics support analysis, configuration definition, and functional analyses and allocation of reliability and maintainability factors are conducted. Preliminary System Design occurs during the Demonstration and Validation Phase of the acquisition process. The final stage of the design process is the Detail Design and Development Phase and includes those activities associated with the Full Scale Development phase of the acquisition and concludes with the existence of a physical model or prototype of the new system [Ref. 10: p. 188]. As can be plainly seen, the major design decisions are already made before the end of the Full Scale Development Phase of the acquisition process. If improved maintainability of the system is an objective of the acquisition and incentives to the contractor are the means to accomplish it, contractual implementation of those incentives must be achieved early in the acquisition process.

C. DEFINITIONS

The definitions contained in this section and the acronyms associated with them will be used throughout the remainder of this thesis.

1. Operational Availability (Ao)

Operational availability is the probability that a system or equipment, when used under stated conditions will operate satisfactorily when called upon. It is calculated by dividing the mean time between maintenance actions by the sum of the value for mean time between maintenance actions and mean maintenance downtime. [Ref. 10: p. 67]

2. Mean Corrective Maintenance Time (Mct)/ Mean Time to Repair (MTTR)

Each time a system fails a series of steps is required to repair or restore the system to its full operational status. These include fault detection, isolation, disassembly, repair, reassembly, and checkout. Completion of these steps constitute a corrective maintenance cycle. The composite value representing the arithmetic average of the individual maintenance cycle times is known as Mct or MTTR. [Ref. 10: pp. 36-37]

3. Logistics Delay Time (LDT)

Logistics Delay Time refers to that maintenance downtime that is expended as a result of waiting for a spare part to become available, waiting for test equipment, transportation, or facilities. It does not include active maintenance time but does constitute a major element of total maintenance downtime. [Ref. 10: p. 46]

4. Administrative Delay Time (ADT)

Administrative delay time refers to that portion of downtime during which maintenance is delayed for reasons of an administrative nature such as: personnel assignment priority, labor strikes, personnel training requirements, and organizational constraints. It does not include active maintenance time. [Ref. 10: p. 46]

5. Maintenance Downtime (MDT)

This is the total elapsed time required to repair and restore a system to full operational status or retain a system in that condition. It includes mean active maintenance time, logistics delay time, and administrative delay time. [Ref. 10: p. 46]

6. Mean Active Maintenance Time (M)

Mean active maintenance time is the average elapsed time required to perform scheduled and unscheduled maintenance and excludes Logistics Delay Time and Administrative Delay Time. [Ref. 10: p. 45]

7. Mean Time Between Maintenance (MTBM)

Mean time between maintenance is the mean time between all maintenance actions (scheduled and unscheduled) and is calculated by dividing 1 by the equipment failure rate and the preventive maintenance rate. [Ref. 10: p. 46]

8. Life Cycle Cost

Life cycle cost is the total of all costs associated with a particular weapon system and is calculated by taking the sum of research and development costs, procurement costs, and operation and maintenance costs.

D. SUMMARY

In this chapter the major systems acquisition process was described and the decision milestones, documentation, and acquisition categories were identified. In addition, the design process was discussed and its relationship to the phases of the acquisition process was established. Finally, definitions of terms to be used in subsequent chapters were provided as well as the acronyms associated with them. In the next chapter the concept of maintainability will be discussed as well as the relevant issues concerning its role in the development of a new weapon system.

III. MAINTAINABILITY ISSUES

A. GENERAL

This chapter discusses the issues surrounding the concept of maintainability. The discussion includes a description of the components of maintainability, the role of maintainability in the evolution of the design of the system and its role in the acquisition process, and finally, it includes an identification of the potential areas where trade-offs may occur. Maintainability has a quantitative as well as a qualitative definition, which complement each other to define the term. The purpose or qualitative definition of maintainability is:

> To ensure the new weapon system has the characteristics of material design and installation which make it possible to meet operational objectives with a minimum expenditure of maintenance effort under the same operational conditions in which scheduled and unscheduled maintenance will be performed. [Ref. 11: p. 1]

Quantitatively, maintainability is:

> A characteristic of design which is expressed as the probability that an item will be restored to specified conditions within a given period of time when maintenance action is performed in accordance with prescribed procedures and resources. [Ref. 11: p. 1]

Put simply, maintainability is that element of ILS that deals with the design of a weapon system or component thereof, such that consideration is given to shortening the period of time the system is inoperable because of preventive or corrective maintenance actions.

B. COMPONENTS OF MAINTAINABILITY

The discussion of the components of maintainability in this thesis will focus on the eight major elements which comprise a typical maintenance cycle. The components of maintainability are: delay time, preparation time, fault location time, item obtainment time, fault correction time, adjustment and calibration time, checkout time, and administrative time [Ref. 11: p. 11]. These elements are directly associated with the actions required in a corrective maintenance action. However, since many of these actions are also required in a preventive maintenance action the two types of maintenance cycles will not be differentiated in the discussion that follows.

Delay time is the first element to be considered. Delay time is defined as the time lapse between the occurrence of the failure and the technicians response to the call for maintenance. Delay time originates from two different sources. The first, fault detection, can range in time from a few seconds in automated systems or systems with extensive built-in-test equipment to several hours in manually operated systems. Fault detection time becomes a significant factor in systems operational readiness testing and normal operations when operational availability is a primary requirement. The second component of delay time involves technician notification and is essentially a communication task, which accounts for the time period between systems failure and the technician's response. [Ref. 11: p. 9]

The second element of maintainability is called preparation time. Preparation time is simply the time it takes to gather the tools and equipment necessary to perform the maintenance. This time occurs prior to the commencement of repair work and would include any time required to obtain additional tools after repairs began. Influences on preparation time include location and manner of storage of tools and test equipment as well as the number and varieties that will be required. [Ref. 11: p. 9]

The third element of maintainability is fault location time, which is the time required to localize, gain access, and identify the failure. Fault location is composed of three elements. The first, fault localization, is the time required to determine which major component of the system is down. This is accomplished through the use of malfunction symptoms, test equipment, or other features built into the system. In manual systems this can be an extremely time consuming task, often the result of trial and error methodology in trying to localize the failure. The second element of fault location is gaining access to the failure. This is the time required to open the equipment and remove any parts that interfere with troubleshooting and replacement operations. Types of fasteners used and the size, type, and location of access openings influence the time required to gain access to the failure. The final element of fault location is failure isolation. In manual systems this element often accounts for more time than any other task in the cycle and may account for as much time as all others combined. The trial and error methodology necessary to isolate the failure often results in excessive time spent in this element. However, even in automatic systems failure isolation can be extremely time consuming task unless the system is automated down to the individual part level, creating a system which is often very expensive to produce. Fault location is probably the biggest area in which improvement can be made in the early stages of the design of the system. [Ref. 11: p. 9]

The fourth element of maintainability focuses on the time required for the technician to obtain parts, assemblies, or units needed for the maintenance action. This time, item obtainment time, includes the time required to identify the item, prepare the requisition, obtain the part from the storage area, and return to the repair area. Backorder time is not considered here, but is included in the Logistics Delay Time (LDT) as part of the total Maintenance Downtime (MDT). [Ref. 11: p. 9]

The fifth element of maintainability is the time it takes to perform the maintenance on the failed item either in place on the equipment or to replace the broken item with a replacement obtained earlier. The fault correction time can range from a few minutes to several hours. The mean of these times taken over a number of maintenance actions is commonly referred to as the equipment's Mct. [Ref. 11: pp. 9-10]

The sixth element is the time necessary for recalibration, retuning, and adjustments required because of differences between the original item and its replacement. This period is known as adjustment and calibration time. [Ref. 11: p. 10]

The seventh element is called checkout time and is the time required to reassemble and checkout the equipment. Reassembly time measures the time necessary to replace the items removed during disassembly and maintenance. The second component, checkout, is the time required to determine if the equipment is operating properly and can be returned to service. [Ref. 11: p. 10]

The final component of maintainability is administrative and logistics time and includes downtime due to backordered parts, lack of space, test equipment, or maintenance facilities, and all the time due to nonavailability of personnel caused by administrative functions. This component is commonly referred to as Administrative Delay Time (ADT). [Ref. 11: p. 10]

Over a weapon system's life cycle hundreds of maintenance actions will be required and they follow the general pattern just described. The average time it takes to complete this cycle is known as the Mean Time To Repair (MTTR) for the system. However, notice those components of maintainability that are really susceptible to being influenced by the design of the system's hardware. The designer of the system can influence only three of the eight components described, because only three are strictly equipment related. The first of these is delay time and it can be shortened significantly through the use of Built-in-Test Equipment (BITE) designed to improve fault detection and notification. Early fault detection often prevents further damage and reduces the cost of repairing systems or components that fail as a result of the first failure. Fault location is the second component that can be directly influenced. The time required to localize, gain access, and isolate the fault can be shortened with the appropriate use of BITE, the proper placement of access panels, fasteners, and components, and the thoroughness of the technical publications that accompany the equipment. The final component of maintainability that can be influenced by design is calibration and adjustment time. Here again, BITE, test site and jacket placement, and test procedures help shorten that time. The other elements of the ILS plan such as supply support, maintenance planning, personnel training, personnel availability, and transportation and facilities determine the remaining five elements of the maintainability of a new system. The designer may have an affect on these elements through his recommendations to the ILS planners but it will not be the same as the affect he can directly apply to the hardware design itself.

C. IMPACT OF MAINTAINABILITY

One of the major objectives in the acquisition of any new weapon system is to acquire the system that most effectively satisfies the mission need [Ref. 8: p. 3]. A measure of the system's effectiveness in which maintainability has a pronounced effect is the life cycle cost of the system. This is most noticeable in the support costs that accrue during its life. Studies have shown that improved maintainability in a system significantly lowers the maintenance costs by reducing the labor hours and spares required to maintain it [Ref. 12]. These savings generally accrue during the operating life of the system and are difficult to measure in the early phase of the acquisition. As one contractor representative stated during an interview:

> The buyer wanted it yesterday; he wasn't concerned with the supportability of it, all he wanted was a system that could perform now. It wasn't until after the system was fielded did he worry about supportability and then it became really expensive to provide the support package he wanted.

Developing support packages after the deployment of the system is not an uncommon occurrence. Seven of those personnel interviewed stated that when the budget became tight the support for the system generally was the first area to be cut. One of those interviewed stated that during a production contract negotiation in which he was participating:

> The Government buyer asked how much maintainability he could get for $75,000; the contractor told him and the buyer deleted the entire item.

The problem these incidents point out is that maintainability is not being considered as a design objective of the new system as a means of reducing the life cycle costs, but only as something concrete that can be added or deleted to the system if there is a spare dollar in the budget.

The previous chapter stated that the design process is evolutionary in nature and, as in nature, this process starts from the basic foundations laid during the earliest phases of the acquisition process. As those interviewed stated:

> This means that during the pre-concept exploration period that clear, concise objectives regarding maintainability for the new system must be considered. These objectives should consider the priority maintainability receives in funding as well as the desired objectives for such measures as MTBM, MMH/OH, MTTR, and Ao.

They also said that during concept exploration these objectives need to be communicated to those industries, laboratories, and universities developing these concepts. The objectives should not be communicated in terms of hardware or configuration because this would constrain the designer. As one interviewee related concerning the development of the MX missile:

> By telling us it had to be a three stage missile vice a two stage one our ability to design the most maintainable one was impaired because that dictated the placement of access panels and complicated the design by adding additional components to the system.

During the demonstration and validation phase of the acquisition when preliminary design is underway, the achievability of maintainability objectives can be used as a means of determining which designs to pursue [Ref. 10: p. 186]. Finally, as the design matures into a piece of hardware during full scale development the maintainability of the items produced as prototypes can be tested [Ref. 12].

Maintainability is not something that can be added to a system; it must be designed into it and therefore, must be considered from the initiation of the program [Ref. 12]. Maintainability is not an entity unto itself and is usually designed into a system at the expense of something else; trade-offs become necessary [Ref. 12].

D. TRADE-OFFS CONSIDERED

Many trade-offs exist when discussing maintainability and reliability; most of these are parametric trade-offs such as weight vs. performance, maintainability vs. weight, reliability vs. life cycle cost, and many others that can be developed. Two of these trade-offs, maintainability vs. reliability and life cycle cost vs. maintainability, are emphasized to demonstrate : (1) the relationship that exists, (2) that changing one parameter affects another parameter of the system, and (3) that trade-offs cannot be accomplished in a vaccuum. The first is the trade-off that exists between the maintainability and the reliability of a system. The nature of the relationship is such that as more maintainability is designed into the system the reliability of the system decreases due to the increasing complexity of the equipment and the need for additional systems to ensure rapid failure detection and location [Ref. 12]. As far as the contractor representatives interviewed were concerned, unless directed to do otherwise, their efforts would be to keep the reliability portion of that relationship high at the expense of maintainability. They indicated that the adverse publicity and impact on future business is greater on a system that is constantly failing than the damage to business caused by the extended amount of time it requires to fix a particular system. Further, interviews with Government and contractor personnel confirmed that the contractor performed the bulk of the detailed trade-off and decision analyses because the buying office generally did not have the "tools or the time" to prepare such analyses.

The other trade-off considered concerns the relationship that exists between life cycle cost and maintainability. Assuming that a balance has been reached between reliability and maintainability and that maintainability has been designed into the system; even though the initial acquisition costs will be higher, the cperating costs of the system will be less than if maintainability were not considered. The savings that result will be generated by the reduction in man-hours spent in the maintenance of the equipment, the savings generated because unnecessary spares are not purchased, and the improved operational availability of the system. This trade-off is hard to demonstrate to a program manager at the initiation of a program because he is constrained by a limited budget and funding for the operating and maintenance costs in which the savings will accrue are programmed from another source.

E. SUMMARY

This chapter provided a discussion of the concept of maintainability. Also in this chapter, maintainability was divided into its eight components. The chapter identified those components that the hardware design could influence and described the impact of maintainability on the life cycle cost of the system and its role in the acquisition process. Finally, the chapter described the trade-offs involved between maintainability and reliability and maintainability and life cycle cost. The next chapter discusses the issues and concepts surrounding the use of incentives in contracts.

IV. INCENTIVE ISSUES

A. GENERAL

This chapter discusses the concepts and issues involved in the use of incentives in defense contracts. Some of the issues this chapter discusses include: (1) the significant characteristics of an incentive; (2) the factors that motivate the contractor to do business with the Government; (3) the functions and types of incentives; (4) the role of uncertainty in incentive contracts; (5) the current structures of incentives in defense contracts; and (6) when to use incentives in defense contracts.

The American Heritage Dictionary defines an incentive as "something inciting to action or effort, as the fear of punishment or the expectation of reward; motivation." [Ref. 13: p. 664] In acquisition, the concept surrounding the use of incentives is that they are generally employed to motivate the contractor to place extra effort in a particular area of the contract and are designed to serve as a reward for that effort. This usually means increasing the contractor's profit in response to the contractor satisfying some predetermined objective. There are five basic functions of incentives as applied to the acquisition environment. The first function is to attempt to distribute some of the risk of development programs between the contractor and the Government. The second function of an incentive is to communicate the Government's objectives in a particular program by targeting those areas in which the Government desires the contractor to concentrate his efforts. The third function of an incentive is to allow the contractor to make cost, schedule, and performance trade-offs when designing a system. The fourth function of an incentive is to help alleviate industry claims that a gap exists in the free enterprise system. The last function of an incentive is to motivate the contractor. [Ref. 14: p. 30] However, incentives to date generally have not done well in accomplishing contractual objectives, but seem to have shown value in directing contractor attention and in assisting communication among the contracting parties [Ref. 14: p. 30]. One factor that seems to contribute to the lack of effectiveness of incentives targeted at cost, for example, is the low share that the contractor must pay for any cost overruns [Ref. 15: p. 242]. As Irving Fisher stated in a study conducted for the RAND Corporation,

> Incentive contracts probably are not saving the Government much money through increased efficiency and better cost control. Consequently, the merits of incentive contracts will have to be judged on other grounds. [Ref. 16]

Incentive contracts in the past have generally targeted cost, schedule, and management performance of the contractor. The reasoning for the past approaches to incentive contracting may have been an overemphasis on the risks involved in the development of a new weapon system [Ref. 14].

B. INCENTIVES AND RISK

In every new weapon system acquisition, risk abounds; it exists in the technology of the proposed system, the costs estimates of the system, the proposed schedule for the system, and the achievable performance levels of the required system to name a few. Risk defined in the context of acquisition is "the possibility of an unfavorable deviation from expectations; that is, the occurrence of an undesirable contingency." [Ref. 17: p. 3] Most businesses, when acting as a whole, tend to be risk averse, that is, they prefer perfectly certain investments to uncertain ones with an equal but uncertain return [Ref. 18: p. 206]. The Government, on the other hand, is generally classified as risk neutral for the following reasons: (1) the wealth of the Government is high in relation to the value of the individual decision to be made; (2) the Government's significant ability to pool the risks involved; and (3) empirical evidence showing the Government's willingness until the mid-1960s to negotiate pure cost-reimbursement type contracts [Ref. 15: p. 20]. Hence, in an effort to control cost overruns, delays in schedule, and poor performance in new weapon systems, the Government was willing to accept a greater share of the risks involved in developing the system by entering into incentive arrangements that split the savings that resulted from cost underruns or the excess costs that resulted from cost overruns [Ref. 15: p. 14].

C. INCENTIVE STRUCTURES

There are two basic structures for incentive arrangements currently in use today. One structure involves the use of a share ratio that divides the difference between the actual costs incurred on a contract and the target cost of the contract according to a predetermined ratio that awards or assesses a proportion of the savings or overruns to the contractor and distributes the remaining share to the Government. This structure is used primarily to motivate the contractor to stay under the target cost on a particular contract, the theory being that the contractor will be motivated to control costs if they share in the savings that result. However, there is some doubt as to the effectiveness of this sharing of savings in being motivating to the contractor to reduce costs [Ref. 14]. Recent studies have indicated that the share allotted to the contractor has not been large enough to motivate the contractor to control costs or alter his approach to cost control [Ref. 14].

The other incentive structure is the award fee. The award fee concept is usually targeted toward performance and delivery requirements, program milestones, and management goals in a contract and involves the establishment of rewards to be given, either in whole or in part, to the contractor periodically upon demonstrated performance in one of the targeted areas. These areas are usually reviewed on a regular basis and awards are made based upon these periodic reviews. Contractor personnel interviewed stated that they favored the use of the award fee structure because it required the contract to specify the requirement, the test criteria, the time of the review, the amount of the award, and generally made the objective of the incentive very clear and concise. They felt that the use of the award fee allowed contractor management to make choices about which incentives to pursue, helped them place a value on the incentive, and helped motivate those people that worked on the incentive because it could be stated as a clear objective for the program. An award fee could be publicly displayed as a goal for the work force to attain and could be used to help explain the extra effort required to deliver a product ahead of schedule. Eight of the twelve contractor personnel interviewed felt the objectivity that they had experienced in the incentive structure in award fee contracts made it a more effective motivating tool than the share ratio structure.

D. SIGNIFICANT CHARACTERISTICS OF INCENTIVES

What are the significant characteristics of an incentive? This question was asked of all the personnel interviewed for this study. The answers to the question were as diverse as those who answered it. However, those interviewed generally agreed that an effective incentive should contain at least the characteristics described below.

The first and most important characteristic of an incentive should be its positive approach. The incentive should be a reward for performance rather than a penalty for failure to perform. The warranty and the Reliability Improvement Warranty are good examples of a negative incentive or penalty approach. The contractor is motivated to build a system that does not fail because of the implications of the warranties in the contract. They said the warranty represents a duplication of effort because if the contractor produces systems that do not perform they will not remain in business for very long. Those interviewed generally agreed that negative incentives do not motivate them to produce any more than the minimum specified requirements of the contract. Further, they said, these warranties were not just given away; that the Government paid a great deal of money for them and often encountered difficulty enforcing them. They felt that this negative approach created unnecessary animosity between the Government and the contractor. They also pointed out that the contractor has as much at stake as the Government in a major weapon system acquisition and that if the system fails it only hurts business in the long run. They indicated that the development of a major weapon system is a team effort and that a positive approach to solving the development issues was more conducive to the kind of performance desired of the system. They recognized the need for warranties and did not object to them in contracts they had, however, they resented the use of the warranty as a tool to induce performance. They felt a positive approach using a reward for performance above the minimum target specified would be more effective in stimulating the contractor and would probably not cost any more than the negative alternative.

Another characteristic the interviewees listed for an incentive was recognition. They felt that an incentive should recognize superior performance as well as superior performers. The interviewees pointed out that the Government and public were quick to recognize the failures of a contractor and very slow to recognize the accomplishments. They also stated that Government recognition of the superior performance of the engineers, assemblers, and other manufacturing people was lacking. They acknowledged that the recognition they described was really a corporate function, but the contractors said it would really be a morale booster if the Government acknowledged, if even only by letter, that the employees of XYZ corporation surpassed the quality requirements of a contract and delivered a product that won an incentive award specified in the contract. They indicated that those responsible for the achievement of the incentive went unrecognized and sometimes were not aware that an incentive was won.

The interviewees mentioned another characteristic of an incentive, that is, it must challenge the contractor. Some felt that the incentives offered for superior performance in contracts they currently had were not challenging. In fact, one interviewee stated regarding some of the incentives on the F/A-18 program that many of the reliability standards established as goals for incentive awards were too easy. A contractor stated that his company considered many of the performance criteria established by the Government well within their capablities and worked as though the criteria were just the minimum specifications to be met on the contract. Their company was not challenged to go beyond their capabilities. "The higher the intended level of achievement the higher the level of performance." [Ref. 20: p. 163] People tend to concentrate their efforts towards those areas that yield the highest rates of reinforcement [Ref. 20: p. 167]. Challenge is a form of reinforcement. The contractors felt that the incentives established should be sufficiently challenging in order to put some uncertainty into the achievability of the incentive. It should be challenging but not unrealistic. The interviewees also acknowledged that it is quite easy to look back and say an incentive was too easily met and quite another to attempt to develop an incentive during Concept Exploration that is realistic and challenging when the concept to solve the mission requirement has not yet been established.

Another significant characteristic mentioned by those interviewed was timeliness. The timeliness they refer to has to do with awarding the contractor the rewards stated in the contract when the reward is earned. They stated that many times the award of the incentive reward was given well after the engineers or other manufacturers who achieved it had left the company or began work on another project. They felt that too often the incentive was paid as a share of savings and was hidden in payments to the contractor long after the incentive goal was attained. They preferred to see the incentive paid when it was demonstrated that the performance goal had been met.

The last and most significant characteristic of an incentive according to the interviewees was that it should motivate the contractor to perform. They felt the incentive should be challenging enough to pose a question of uncertainty as to its attainment. They felt the incentive must be clearly established, concisely worded, and objectively tested to determine the contractor's success or failure in meeting the incentive requirement. They felt that the reward for accomplishing the incentive should reflect the risk involved in attaining it. The ability to motivate is the hardest characteristic to build into an incentive because it requires that the Government understand what motivates the contractor they are dealing with at the time. The same factors that motivate one contractor do not necessarily motivate another.

E. CONTRACTOR MOTIVATION

Before meaningful incentives can be formulated for a new weapon system, there must be a clear understanding of what it is that motivates a defense contractor to do business with the Government. To understand how to motivate a defense contractor:

> You must recognize that you are dealing with people formed together to make up an organization. The goals and intentions of the individuals are expressed in the goals and intentions of the organization. [Ref. 19: p. 19]

Every management student is aware of Maslow's "hierarchy of needs" theory that describes human development in terms of satisfaction of increasing levels of needs from the need to meet the bare physiological requirements of life to achieving the self-actualization he desires as his simpler needs are satisfied [Ref. 21: p. 32]. However, most do not realize that a corporation also has a hierarchy that it seeks to satisfy as it matures and grows during its life [Ref. 21: p. 34]. Some of these needs or stages a corporation encounters during its life are: survival, profit, market share, and prestige. Understanding the stage of development a contractor is in is the key to understanding the best way to motivate it. Put simply, a contractor just entering the business is seeking to satisfy survival needs. That means he is interested is getting all the business he can get. After satisfying the basics of survival the contractor will direct his efforts more toward increasing his profit. As the contractor grows profit will still be a concern but he will direct his efforts toward more company growth. As his growth needs are satisfied the contractor will seek to increase his market share of the industry. As all these needs are satisfied the contractor will seek to satisfy the need for prestige for the company. They will attempt to become known throughout the defense industry as the best producer of aircraft or ships and when a tough problem arises they will attempt to become known as the ones to call. [Ref. 21: pp. 38-40]

The perspectives of Government and industry are different as to what motivates a contractor.

> The Government perceives short-term monetary objectives such as profit, cash flow, and return on investment as the key motivators. The contractors express more interest in the long-term strategic objectives such as company survival and growth and the reputation objectives of producing a quality product and ensuring proper performance. Both parties agree, however, that profit is one of the key factors, and that incentive fees which can result in higher profits are an effective means of motivating the customer. [Ref. 22: p. 51]

Government and contract representatives perceived monetary rewards such as incentive fees to be the most effective types of incentives. Second in perceived effectiveness among both groups were the risk reducing types of incentives such as capital investment protection and long-term funded contracts. [Ref. 22: p. 51] Some disincentives were also identified in the literature and were verified by the contractors interviewed. These included excessive regulation, socio-economic requirements, unallowable costs, and

Cost Accounting Standards; however, the top three disincentives were: excess Government interference, excess paperwork, and program instability resulting from poor Government planning. [Ref. 22: pp. 51-52]

In order to motivate a contractor motivation must occur on two levels. First, it is necessary to motivate the corporation and second to motivate the people that make up the corporation. To motivate the contractor, planning must start before the contract award. The Government must assemble information on the objectives of the acquisition, the internal and external constraints on the Government's behavior during the acquisition, the contractor's objectives, and any constraints on his behavior [Ref. 7: p. 59]. The Government must understand that industry places more interest in long-term profit objectives (a good product and continuing business relationships) than it does on short-term profit [Ref. 7: p. 75]. To motivate a contractor on the second level, the employees, it is necessary to understand what motivates people to do what they do. Frederick Herzberg pointed out that the motivation to perform a task must be developed from within the individual and that the best that managers can do to motivate their employees is to create an environment that ignites those desires within them [Ref. 23]. It must be recognized that what motivates people varies with people and with situations [Ref. 24: p. 645].

Six factors which do create the situations needed to motivate employees are:

> (1) The challenge found in the work. If this is to be minimized, people must know the purpose and scope of their job responsibilities, what their authority is, and what is expected of them, and they must have a belief in the value of what they are doing. (2) Status. It includes titles, promotions, and such symbols as office size and appointments. (3) Leadership, that is, the urge to be a leader among ones peers or in ones field or industry. (4) Competition. The realization that others are competing for the job, instant contract, or market position of the company. (5) Fear, this takes many forms, including fear of error, failure, loss of a job,

or a reduction of a bonus or salary. (6) Money is a very effective motivator; most often it is more than mere money, it is the prestige that accompanies it when an award is received. [Ref. 25]

In order to motivate a contractor the Government must understand where it stands in the evolution of the business and what the contractors needs are. Further, the contractor must be motivated from two levels, the corporate level through an understanding of the corporate objectives, and at the people level through an understanding of the factors that motivate people to do their best effort.

Contractors interviewed stated that a number of factors motivated their companies to do business with the Government. First, they felt the business was relatively stable. The contractors indicated that even though the intensity of the business and the volume of defense work shifted from time to time there was sufficient work to make it a viable industry. Second, they felt there was a definite need for their product and that the need would continue to exist. Third, they stated a patriotic reason for their participation in defense work and felt they were making significant contributions to the defense of this country. Finally, they stated that defense contracts were generally very profitable. They said some contracts were more profitable than others but overall the return on investment in defense contracts was very respectable. It is important to realize that defense contractors are businesses and to exist they must satisfy the basic function of a business: to create a customer [Ref. 26: p. 61]. The customer is created by contractors directing their attention to two basic activities, marketing and innovation [Ref. 26: p. 61]. Defense contractors do business with the Government because the customer exists, it's profitable, the market can grow, and it provides an arena for innovative technology that can be applied in the commercial activities of the industry.

F. INCENTIVES: WHAT AND WHEN?

The inteviewees were all asked what would motivate them to spend more design effort to improve maintainability in new systems and they provided two basic answers. First, they said that if the Government were willing to invest more money in the development of more maintainable systems the contractor would design as much maintainability into the system as desired. Their second response was that their greatest fear was failure to perform to the level required by the contract. They said that if a maintainability parameter was stated in the contract that was achievable, demanding, and realistic that they would treat it as a specification and put the design effort in to accomplish it, but would adjust the price of the contract accordingly. They much preferred, however, that more positive approaches to improving maintainability be used and recommended that positive incentives be used rather than the fear of failure as the key motivator. "Big fears— If misused to drive disciplinary devices can cause only resentment and resistance, they can only demotivate." [Ref. 26: p. 237] In the case of defense contractors they felt that appeal to the profit motive would be a very effective incentive. "The first test of any business is not the maximization of profit but the achievement of sufficient profit to cover the risks of economic activity and thus to avoid loss." [Ref. 26: p. 60] The contractor's desire to avoid economic risk and loss of profit can also be used to motivate the contractor. Those interviewed felt that program stability and multi-year procurements were two viable means of motivating the contractor without having to resort to the use of exaggerated levels of profit. Program stability would help to permit the contractor to improve his efficiency by encouraging the contractor to invest in equipment and facilities that he might not necessarily do if the program's survival was in doubt from year to year. Multi-year procurement can also motivate the contractor and reduce the economic risk and possibility of loss of profit he faces in every new system. In multi-year procurements the contractor may take advantage of economic opportunities in purchasing materials and in establishing production runs that promote efficiency, reducing the risk to the contractor and the cost to the Government. Contractors also favored the use of incentives to motivate maintainability improvements because they put some of the decisions on which objectives to pursue during design in the hands of the designers.

When asked when to use incentives, all those interviewed were in agreement that incentives should be utilized throughout the development and production of the new system. They felt that the plan to use incentives as well as the targets of the incentives should be communicated to industry as soon as possible. They felt that if the objectives of the program were to develop a system that was highly reliable, maintainable, or supportable and incentives were to be used for that end, then the industry needed to be aware of it at the beginning of concept exploration. Those interviewed stated that it was not necessary to specify the specific parameters of the incentives at this point but only that incentives were going to be used and what general areas were going to be targeted. As the acquisition process progressed and concept exploration concluded, the specific incentive targets could be developed according to the objectives established. In this manner, they felt that the incentives could be tailored to stress those areas that would motivate the contractor the most. For example, at program initiation the DoD component requesting the system specifies that maintainability is to be an objective of the system and funds have been allocated for that purpose.

During concept exploration the program manager ensures that industry is aware of the incentives available, what role if any maintainability will play in the selection process, and what areas are being targeted in maintainability. As alternative concepts are evaluated and the ones to continue into Demonstration and Validation selected, the parameters for maintainability and the potential incentives available can be defined. As Demonstration and Validation continues, the designers can make the necessary trade-offs to design maintainability into the system. When the system enters Full Scale Development, the maintainability of the system can be tested on the hardware developed. As Full Scale Development concludes, the maintainablity of the system can be verified on the prototypes and pilot production models produced. Finally, as the system enters production and use in the fleet, the maintainability of the system can be tracked for the first year or two of its life to determine if the parameters established and tested are valid.

G. SUMMARY

This chapter discussed the concepts and issues surrounding the use of incentives to motivate defense contractors in their design efforts. The chapter included discussions on the structure of incentives, those factors that motivate the contractor and contractor personnel, the significant characteristics of incentives, and why contractors do business with the Government. The chapter concluded with a discussion of the timing of incentives and what incentive means were favored most by contractors.

V. THE INNOVATIVE EXAMPLE OF THE F/A-18

A. GENERAL

This chapter presents an example of how incentives were utilized to improve maintainability on a major weapon system acquired by the Navy. The weapon system presented is the F/A-18 Fighter/Attack aircraft. The system is unique because it represents a genuine attempt to place reliability and maintainability on an equal level with the cost, performance, and schedule requirements of the system. The approach to maintainability as well as an analysis of the reasons for its success are contained in the following.

The F/A-18 program was the first major acquisition program in the Naval Air Systems Command (NAVAIR) to be managed under the disciplines of the "New Look", the purpose of which was to ensure that reliability and maintainability was by design, not by chance [Ref. 27: p. 2]. The F/A-18 program used incentives to motivate McDonnell Aircraft Company (MCAIR) to improve upon the minimum requirements specified in the contract in four areas: reliability, maintainability, life cycle cost, and F/A-18 program milestones [Ref. 27]. The incentive program for improved reliability and maintainability reflects the new emphasis on the supportability of new weapon systems entering the inventory and provides an excellent example of how incentives can be used to motivate the contractor to improve the maintainability of a system under design.

The incentive program for the F/A-18 for maintainability focused on three parameters: Mean Flight Hours Between Maintenance Actions (MFHBMA), System Direct Maintenance Manhours per Flight Hour (DMMH/FH), and organizational level

Maintenance Manhours per Flight Hour (MMH/FH). The total potential award to be won was $12 million and was to be equally divided among the three parameters so that the maximum potential award in any parameter was $4.0 million. The proposed plan called for payment of the awards upon the demonstration at key decision points of meaningful achievement of measurable maintainability. [Ref. 28] The objective of the awards program was to motivate the contractor to exceed the specified maintainability requirements in the contract by attaching monetary awards to maintainability levels achieved in excess of the minimum parameters specified. Payment of the awards was contingent upon demonstrated performance in an operational environment at predetermined times. These demonstrations were conducted at the 1200 and 2500 cumulative flight hours test points on full scale development aircraft and the 9000 cumulative flight hours test point for pilot production aircraft using data gathered during the previous six month period. Each maintainability parameter was evaluated at two different cumulative flight hour demonstration periods. [Ref. 28]

Organizational level MMH/FH was the first parameter evaluated. It was evaluated in two increments with a total potential award of $4.0 million. The first demonstration was conducted at the 1200 cumulative flight hour mark and had a potential award of $1.5 million which the contractor could win if the contractor achieved 8.0 MMH/FH or less on the aircraft. The contractor would earn 50% of that award if he achieved 10.0 MMH/FH and nothing if he reached the minimum target of 11.0 MMH/FH. The contractor achieved a 7.72 MMH/FH and won the full award. The second increment for this parameter was conducted at the 2500 cumulative flight hour mark and had a potential award of $2.5 million. The targets for this increment were tougher than those of the previous increment. If the contractor achieved only 8.0

MMH/FH at this increment he would not receive any of the award, reaching 6.0 MMH/FH would win 50% of the award, and attaining 5.0 MMH/FH would win the entire award. MCAIR reached 3.62 MMH/FH and won the total award for this increment. MCAIR's total award for this parameter was $4.0 million and they reduced the MMH/FH from the minimum target goal by almost 400%. [Ref. 28]

The second parameter evaluated was DMMH/FH and was also evaluated in two increments with the potential award split into $1.5 million at the 2500 cumulative flight hour mark and $2.5 million at the 9000 cumulative flight hour mark. In the first increment the minimum target goal was 20.5 DMMH/FH and earned no award, 50% of the award was earned if the 17.5 DMMH/FH was achieved, and 100% of the award was earned if the demonstrated DMMH/FH was 16.0 or better. MCAIR attained a 6.32 DMMH/FH and earned the full $1.5 million. The second increment was demonstrated on four pilot production aircraft at the 9000 cumulative flight hour mark. The targets were more restrictive than the first increment with the minimum acceptable value to earn any award being 14.4 DMMH/FH and 12.0 DMMH/FH earning 100% of the potential award. MCAIR achieved a value of 6.48 DMMH/FH and won the full $2.5 million for this increment. For the parameter DMMH/FH, MCAIR exceeded the target goal by almost 300% and earned $4.0 million in incentives. [Ref. 28]

The final parameter evaluated was MFHBMA and it too was evaluated in two increments. The first at 2500 flight hours with an award of $1.5 million and the second at 9000 flight hours with a potential award of $2.5 million. The minimum acceptable value for this parameter in the first increment was 0.5 MFHBMA and earned no award, reaching 0.8 MFHBMA earned 50% of the award, and reaching 1.5 MFHBMA earned the total award. MCAIR reached a value of 1.14 MFHBMA and earned $1.14 million for the first increment. The second increment contained more restrictive goals and was evaluated at the 9000 flight hour mark. The minimum target was .75 MFHBMA and earned no award with the maximum award being given for reaching a goal of 1.6 MFHBMA. MCAIR reached the value of 1.31 MFHBMA and received $2.12 million in awards. MCAIR exceeded the targets by almost 200% and earned a total of $3.26 million for this parameter and $11.26 million of the $12 million offered for maintainability improvement. [Ref. 28]

The demonstrations were performed by operational personnel at operational sites. The evaluation plan called for a board of MCAIR and Navy personnel to accumulate the data, evaluate the maintenance performed, determine if adjustments were warranted to any measured maintenance activties as defined by criteria agreed upon by both parties, and finally they determined if award of the incentive should be given and what percentage of the total award would be given for values between targets. Table 1 contains a summary of the target goals, potential awards, attained goals, and earned awards by MCAIR in the F/A-18 program [Ref. 28].

Some of the lessons learned from the experience in the F/A-18 program are contained in the following and are described by acquisition phase. In Concept Exploration the following strong points were identified: (1) High level management (Navy and MCAIR) attention and support of maintainability objectives was essential to getting the results obtained. This attention was the result of briefings to the contractor by high level Navy personnel which included the Assistant Commander for Systems and Reliability, the Deputy Chief of Naval Material for Reliability, Maintainability, and Quality Assurance and the Program Manager for the system. "This high level attention was a major factor in keeping the contractor efforts focused on providing equal

TABLE 1

F/A-18 Maintainability Goals

	Goal	Achieved	Award Max.	Award Earned
MMH/FH				
1200CH	11.0		0	
	10.0		50%	
	8.0	7.72	100%	$1.5M
2500CH	8.0		0	
	6.0		50%	
	5.0	3.62	100%	$2.5M
DMMH/FH				
2500CH	20.5		0	
	17.5		50%	
	16.0	6.32	100%	$1.5M
9000CH	17.5		0	
	14.4		50%	
	12.0	6.48	100%	$2.5M
MFHBMA				
2500CH	.5		0	
	.8		50%	
	1.5	1.14	100%	$1.14M
9000CH	.75		0	
	1.00		50%	
	1.60	1.31	100%	$2.12M

Source: [Ref. 28]

attention and emphasis with cost and performance to achieve the desired levels of R&M." [Ref. 27] (2) The award fee provisions helped to ensure contractor emphasis on R&M disciplines. The establishment of the firm award fee dollars provided a clear understanding of what was expected in the area of maintainability.

> This provision for award fee for achieved maintainability is considered a prime factor in the motivation and dedication shown by the contractor to correct maintainability problems as they were identified during the development phase. [Ref. 27]

(3) Also during this phase visits by key contractor management personnel and design supervisors to operational sites provided a good insight into fleet concerns and the problems that exist on current aircraft weapon systems. This

provided an understanding of the need for changes in existing design concepts to eliminate or reduce the impact to the fleet of the new system and to reduce the cost of ownership to the user and increase the operational readiness of the new system. [Ref. 27]

During Full Scale Development the following positive actions occurred: (1) Periodic appraisals of contractor performance in the area of maintainability were an effective means of continuously reinforcing the contractors motivation toward maintainability issues. The appraisals were conducted on a quarterly basis and awards were made for performance in life cycle cost milestones and program management milestones. [Ref. 27] (2) Extensive use of Design Reviews and Technical Coordination Meetings assured adequate consideration was given to maintainability requirements during design and testing. During these meetings the maintainability implications of every decision was discussed and stressed the use of trade studies to balance cost, weight, and performance with maintainability parameters. These meetings were attended by R&M design engineers and fleet maintenance personnel to provide an effective means of identifying appropriate maintainability trade-offs. [Ref. 27] (3) A memorandum of agreement between the Navy and MCAIR was negotiated before Full Scale Development flight testing which established a Reliability and Maintainability Review Board. The board consisted of Navy and MCAIR personnel which assessed, verified, and corrected all R&M data as necessary before submission into the Navy and MCAIR data systems. The memorandum described the ground rules for documenting failures, maintenance actions, and manhours during the flight test program and helped alleviate any potential arguments. The Board also provided R&M design engineers with excellent feedback on any problems that developed. [Ref. 31] (4) They integrated the reliability and maintainability activities of the contractor to ensure that the maintainability design baseline and the logistic support analysis used the allocations developed by the contractor rather than independently derived values. In this manner, significant differences in the basic values used to determine spares provisioning and manning levels were avoided. For the F/A-18, the contractor used the engineering activity allocations as the source of data for the logistics planning community. [Ref. 27] (6) Contractor corporate management personnel attended Preproduction Reliability Design reviews. Attendance kept them informed on the impact of R&M and on concerns of the Navy. It was also useful in convincing management to ensure adequate funds and manpower were allocated to the program and were not deleted when other performance problems began to appear. [Ref. 27]

Normally during the production phase of a program engineering effort starts to disappear. However, this was not the case in the F/A-18 program. For the first time on a major system, the contractor's R&M engineers were allowed to follow and track the aircraft into the fleet. [Ref. 27] This monitoring allowed verification of the effectiveness of the numerous R&M corrective actions identified during Full Scale Development which, due to lead time requirements had not been incorporated and evaluated in the aircraft during the Full Scale Development phase. It also provided on-site evaluation and engineering investigation of any new reliability or maintainability problems not seen during the Full Scale Development flight testing. This allowed for the rapid resolution of R&M problems that almost always appear after the formal testing is complete. [Ref. 27] The F/A-18 program incorporated many of the positive criteria for incentives discussed in the previous chapter.

B. ANALYSIS OF THE PROGRAM

An analysis of the F/A-18 program with respect to its use of incentives for maintainability requires consideration of the following: (1) conceptually, should the incentives motivate the contractor, keeping in mind the significant characteristics of incentives and the factors that motivate a contractor as described in Chapter IV, (2) were the goals realistic enough to challenge the contractor or were they merely specifications that were established at too low a level, (3) were the targeted parameters proper or were they too general, and (4) were the award payments for successful achievement or did they amount to funds unnecessarily spent.

Conceptually, the incentives for maintainability in the F/A-18 program were effective for several reasons. First, the Navy made a commitment at the outset of the program that maintainability was going to be a major objective of the program and required that minimum maintainability specifications be written into the contract. Second, MCAIR personnel were provided the opportunity to talk to the customers to ensure that MCAIR design engineers understood the operational environment and the conditions under which maintenance would occur. This fostered an attitude of teamwork between the Government and the contractor. Third, the Navy allocated $12 million for incentive awards for maintainability which helped to convince MCAIR top management that a real commitment to maintainability had been made. Fourth, the awards were designed to be paid as the results of the maintainability demonstrations were established providing timely reward for contractor efforts. Fifth, the incentives were structured as award fees which were clearly identifiable to contractor personnel. Sixth, corporate management used the award program in the contract as a means of motivating their employees. MCAIR developed award programs of their own which provided monetary awards for beneficial suggestions submitted by employees. It also included gifts to employees consisting of models of the aircraft, coasters, and other memorabilia all designed to help maintain employee enthusiasm for the project. Finally, the incentives were targeted to specific parameters such as MMH/FH, DMMH/FH, and MFHBMA and the minimum acceptable levels for these parameters, the conditions of testing, definitions of test objectives, and other parameters were mutually agreed upon and included in the negotiated contract. The incentives were effective because the contractor was motivated. This motivation stemmed from the following: he was treated as a team member, he was involved early in the program decision process, his design engineers as well as corporate management were involved in working toward the awards, the awards were a substantial amount of money, the contractor directed design efforts toward attaining the maintainability goals, and the contractor possessed the technical capability to meet the maintainability objectives stipulated. [Ref. 31]

The second area of concern focuses upon whether or not the incentives did motivate the contractor's performance. This issue involves the values for the parameters established in the awards payment plan. One Government representative indicated that the values for the parameters were too low and that if presented the opportunity to reconstruct the incentive program he would make those parameters much more stringent. His opinion was supported by a contractor representative with experience on the project who indicated that the parameters established were well within the company's capability so they treated the parameters as they would any other contract specification. Even though the contractor directed significant attention to the targeted areas, he indicated there was never any doubt that the company would earn a significant portion of the available incentive award.

The long range effectiveness of the money spent on these incentives is yet to be determined. However, as the data in Table 2 show for CY 1983 after an accumulation of 23,881 flight hours by the F/A-18, those areas targeted for incentives reflect a distinct improvement in performance over other aircraft in the fleet. The MFHBF for the F/A-18 was more than twice that of its nearest competitor, the F-4J/S. The organizational level MMH/FH was less than half the value of the A-6E and substantially below that of the A-7E. The real effectiveness of the awards program will not be realized until later when improved aircraft availability and operational readiness of the F/A-18 can be demonstrated. [Ref. 32] The conclusion that can be reached is that even though the objectives may have been too low to challenge the design capabilities, the potential award was sufficient to keep the contractor interested in maintainability and helped to provide an aircraft with reliability and maintainability superior to anything in the current Navy inventory.

TABLE 2

R&M Parameters of Fleet Aircraft (CY 1983)

Aircraft	FH	MFHBF	MMH/FH	MMH/FH*
A-6E	71,610	0.59	23.70	7.8
A-7E	107,200	0.66	17.38	6.1
F-4J/S	46,904	0.72	24.32	7.8
F-14A	94,258	0.61	24.89	7.5
F/A-18	23,881	1.69	10.47	3.6

*- scheduled maintenance

Source: [Ref. 32]

The F/A-18 program targeted three parameters for incentives: MMH/FH, DMMH/FH, and MFHBMA. These parameters are very broad categories and as such required extensive definitions of what constituted a maintenance action, a failure, what time was considered productive and nonproductive for purposes of maintenance labor computations as well as others too numerous to mention here. Appendix C contains the definitions for accountable and nonaccountable labor as considered in the computation of the maintainability parameters. [Ref. 29] These definitions were necessary because of the broad scope of the criteria selected for measurement and incentive targeting and were needed to ensure that the values of the parameters were properly computed. The broad scope of the parameters chosen and the numerous assumptions and definitions required as a result made the award process more subjective than was necessary.

The F/A-18 program contained minimum specifications for other parameters as well. Among these was a required fault isolation time which specified that 95% of the faults must be isolated within a time period of five minutes; the remaining 5% of the faults must be identified within ten minutes. However, no incentives were attached to this parameter. This was a valid candidate for an incentive because it would have an effect on all the general parameters stated in the incentive plan and would have influenced the designers to focus more attention on the design of the Built-In-Test-Equipment (BITE). The BITE capabilities were also outlined in the contract and did not have any incentives assigned to it. As a result of the lack of incentives, these items did not receive the same level of attention as that received by the other parameters. Consequently, BITE was one of the weakest areas of the whole system [Ref. 30]. The rationale for targeting the general parameters was the belief that they would drive the design of the specific values for fault isolation, fault location, and other related measures [Ref. 30]. The result, however, was that by designing to lower the values of the broad areas, the influence of a particular element that composed that value could be minimized.

From the interviews for this study, it was determined that a better approach would be based on a different sequence of parameters. The first parameter would be delay time and the incentive would be targeted specifically toward shortening the length of time required to detect the fault. The second parameter to be targeted would be fault location and the incentives would be targeted specifically toward shortening the time it takes to localize the fault, gain access to the failed component, and isolate the failed part. The third parameter would be the time necessary to adjust and recalibrate the system after maintenance is completed. As was stated in the chapter on maintainability, these three elements are directly hardware related and by specifying challenging targets in these parameters and attaching significant incentive awards to them, the design engineers would be motivated to design the hardware with these considerations in mind. To significantly shorten these times, the designers would be faced with solving the engineering problem with either the addition of more BITE, simpler hardware, or a combination of the two. If successful in shortening these times, the maintenance cycle and the cumulative values of maintainability such as MTTR and MMH/FH would be reduced. These parameters would be identified during Concept Exploration and definitized during Demonstration and Validation. The demonstrations and testing for award purposes would occur during the Full Scale Development phase of the acquisition.

The parameters described above would stimulate the designers to design maintainability into the system. To ensure that the engineering efforts continue, two other parameters could be targeted for incentives: (1) establish incentive awards for MTTR objectives and (2) establish an award schedule for operational availability. The purpose of these incentives would be to maintain contractor interest in maintainability during the Full Scale Development and early Production and Deployment phases of the acquisition. Although these elements are not strictly hardware related, significant incentives in this area may motivate the contractor to develop more efficient and informative technical publications and maintenance procedures for the system.

It is important that whatever parameters are selected, they be objectively attainable and demonstrable during the testing and award process. The parameters should be constructed so that the contractor does not ignore one aspect of the system to achieve an award in another area. During the F/A-18 program one of the weakest areas of the system was its BITE. The contractor pursued the R&M incentives at the expense of BITE which did not have any incentives targeted to it. As a result, the F/A-18 was inundated during the testing of the system with false alarms which caused confidence problems among Navy and MCAIR maintenance personnel [Ref. 32]. The sole use of the cumulative maintainability parameters was partially responsible for this because some of the maintenance actions and their associated times caused by BITE failures could be assumed out of the calculation of the targeted parameters. Targeting the incentives to specific values such as delay time, fault location time, or failure isolation time would help eliminate much of the subjectivity involved.

C. SUMMARY

In this chapter an example of a successful application of incentives for improved maintainability was presented. The awards payment plan and the incentive parameters used in the F/A-18 program were identified and an analysis of the reasons for the success of the program as well as possible areas for improvement were identified.

VI. ANALYSIS OF THE PROBLEMS AND ISSUES IN INCENTIVES FOR MAINTAINABILITY

A. GENERAL

This study has discussed the components of maintainability, its role in the acquisition process, its impact on the life cycle costs of a weapon system, and its role in the design of a weapon system. In addition, the issues and concepts involved in the use of incentives to motivate contractor performance were also discussed. Further, the study provided an example of a major weapon system acquired by the Navy in which incentives were used to motivate the contractor to direct his attention to the maintainability characteristics of the system as well as other program objectives of the Government. The case demonstrated a successful application of incentives to improve the maintainability of a new system. However, the fundamental question still remains as to whether it is appropriate to use incentives for the purpose of improving maintainability. If it is assumed that it is appropriate, then a number of questions as to how it would be accomplished immediately arise. This chapter will address questions concerning the appropriateness of incentives for maintainability improvement, the structure of the incentive plan, and other maintainability issues that should be considered.

B. APPROPRIATENESS OF INCENTIVES

The question of appropriateness of using incentives for maintainability improvement was initially answered by those interviewed from a parochial view. They were viewing the issue from their own company product or Government position.

From that limited perspective, those interviewed were split as to the appropriateness of using incentives to improve maintainability. One Government official related that incentives were not necessary to motivate the contractor to design maintainability into a new system; that if the Government could determine the level of maintainability it desired in the system then that level should be specified in the contract and the contractor's failure to achieve that level would be tantamount to nonperformance. He stated that it was not desirable to use incentives because of the associated administrative burdens that accompany them and a much simpler method of accomplishing the same objective was available. He also stated that he was not convinced that the money needed for the incentive awards would really buy any more maintainability. Similarly, an engineer for a missile producing contractor concluded that it clearly was not appropriate to use incentives for maintainability improvement in missiles. The emphasis, he said, was on reliability since the nature of the weapon mandates successful performance on demand. His rationale was if the missile worked, it was destroyed. If it did not, the probability was also high that it would be destroyed either through enemy action or through the user's action to protect himself during landing or disarmament operations. However, these views were in direct contrast to those expressed by other contractors; especially those involved in the design of integrated systems. One program manager enthusiastically supported the use of incentives for maintainability improvement in systems on which he worked. He stated that the technology existed to improve the maintainability of the system he supervised but the Government was satisfied with the existing maintainability level and was not willing to fund any improvement. As a result, he said, there was no motivation for him to put more design effort into the product. Another contractor interviewed stated that incentives were more appropriate for weapon systems with new technology than it was for the mature technology in older systems. He stated that it would be more appropriate to use incentives in the Midgetman program because of the flexibility available in the design of that program that was not now available in the older Minuteman system.

When asked to respond to the issue on a more generic level, the contractors interviewed responded more favorably toward the idea whereas the Government representatives were more reluctant to endorse such a plan, presumably because of the extra burdens it placed on the administration of the contract. Government representatives interviewed felt that incentives were inappropriate because their effectiveness could not be predetermined, they added complexity to the contract, the contracts were more costly to administer in terms of manpower, money, and time, and in general possessed the necessary framework for many more disputes related to the incentive provisions. The contractors generally felt they were appropriate because their use shifted the decision-making process for design trade-offs to the contractor who they felt was more capable of making the trade-off decisions. They said incentives helped to communicate the objectives of the Government in a particular program, it provided the contractor the opportunity to earn more profit as a result of his innovation or efficiency, and it allowed the contractor the opportunity to more effectively manage the risk involved in the system's development.

This study found that the appropriateness of using incentives for maintainability is dependent upon several factors. First, is the mission of the system being acquired. It would be inappropriate to use incentives on a system that is designed to be used once and is either destroyed or discarded afterward, as in most missile systems. It is also inappropriate to use incentives in a system in which the maintenance concept stipulates that only intermediate or depot level maintenance will be performed. The biggest gains in terms of equipment readiness will be made by efficient maintenance at the organizational level. Consequently, the maintainability of a system should be dictated by organizational level maintenance needs.

The second factor that determines the appropriateness of incentive use is the state of technology of the system. If the technology of the system is mature, there may not be any innovative way to design a system to be more maintainable and the potential increases in maintainability will be offset by the design effort to attain it. On a system that is pushing the state-of-the-art, potential gains in maintainability are enormous. The existence of trade-offs in design and materials, the availability of alternate technologies to solve the engineering problem, and the willingness of those involved in the design to be innovative are all factors that assist engineers in improving maintainability.

Another factor which helps to determine the appropriateness of incentives is the maturity of the design. This factor is closely related to technology in that in a mature design, most improvements that could be made have been made through configuration changes or product improvement and the potential gains again would not offset the effort to attain them. The Minuteman system is a good example. It is a mature weapon system that has been in use for a long time. Clearly, it would not be appropriate at this stage in the system's life to try to motivate the producers of the missile to design more maintainability into the system even though periodic changes in the components of the system do occur. On the other hand, the STEALTH program with a design and technology still in its infancy possesses enormous potential gains in maintainability and with a little motivation, the contractors involved may well pursue them.

Finally, one must consider the objectives of the program. If lowering the support costs of the system is an objective, then maintainability incentives may be appropriate. If keeping the acquisition costs of the program to a minimum is the objective, then incentives may not be appropriate because they tend to require more funding at the start of the life cycle of the system than may be tolerable. Contractually, incentives will require more administrative effort and supervision than contracts without them and if simplicity is an objective, then incentives may not be appropriate. However, if the objectives are to stimulate contractor performance, lower the life cycle costs of the system, and produce the most maintainable system affordable, then incentives may very well be appropriate.

Several factors have been mentioned regarding the appropriateness of using incentives for maintainability and from the responses of those interviewed and the literature, it could be concluded that the decision to use incentives must be made on a system-by-system basis. The decision is not one that can be put off until late in a program. It must be made at the outset considering those factors mentioned above as well as any additional relevant issues peculiar to the program or situation involved. If the decision is made that incentives are not going to be used, then an alternate means of satisfying the program's maintainability objectives must be found. However, if the program manager or decision authority decides it is appropriate to use incentives for maintainability improvement, then a number of problems arise that must be addressed before any contracts are awarded. These problems will be addressed in the next section.

C. STRUCTURE OF THE INCENTIVE PLAN

The structure of the incentive plan is another area that must be addressed. Specifically, it concerns the timing and method in which payment will be made after successful demonstration of the parameter. Earlier in the study the share ratio structure for incentive contracts was discussed. Interviewees stated it would be extremely difficult to use this structure for maintainability incentives. The reason for the difficulty is the inability to establish the magnitude of the award until a significant period of time in the operating life of the system has passed. The share ratio would have to be applied to the estimated savings in life cycle costs that would result by achieving a level of maintainability better than that originally specified in the contract. It would also be difficult to equate a dollar value to a specific maintainability parameter's value. It would be hard for a contractor to be very enthusiastic about such an arrangement because it would be difficult for the contractor to determine the value of the incentive. Additionally, the contractor would not be paid the incentive for a considerable period of time after the design effort was completed and the amount of savings that would result would be dependent upon factors other than those the contractor could control, such as personnel training or supply support. The contractor would also have to establish a means of collecting the data from the field. Finally, the complexity of such an arrangement would make it almost useless as a tool for corporate management to motivate their employees. There is, however, an acceptable alternative.

Under the award fee incentive structure, a specific amount of money is established as an award and specific objectives for the contractor are formulated. The contractor's performance is reviewed periodically and a determination of whether or not the award has been earned is made. If the objective has been met, the award is paid. For maintainability incentives the award fee would be more efficient because it can be more objective, it can be periodically reviewed, it is paid in a more timely manner, the potential award is clearly established, contractor management and employees could readily establish the relationship between the effort required to accomplish the incentive and the expected payoff that resulted, and it would be a much simpler instrument to draft and administer in the long run. The F/A-18 program used the award fee structure for its reliability and maintainability incentive program very successfully.

D. OTHER MAINTAINABILITY INCENTIVE ISSUES

In Chapter IV, the significant characteristics of an incentive were described. These characteristics were: (1) a positive approach (ie., reward accomplishment rather than penalize nonperformance), (2) recognition of achievement, (3) the challenge of the incentive, (4) timeliness of award of the incentive, and (5) the incentive must motivate the contractor. In addition to those characteristics of an incentive, the chapter also described four issues to consider when constructing incentives to motivate a contractor. These are: (1) attempt to construct an incentive that can be used by management to motivate the employees of the company as well as its management, (2) attempt to ascertain the contractor's needs by determining the stage of maturation of the company, (3) realize the appeal to the profit motive is a good motivator throughout the maturation process and is the easiest to use, and (4) understand that other risk-reducing incentives are available. Two examples of additional incentives that might be used are multi-year procurement and capital investment incentives. These must generally be done before the work is initiated and the incentive demonstrated and will be hard to sell to the decision authority because of regulatory requirements and the fact that successful accomplishment of the incentive cannot be guaranteed.

However, once the decision has been made to motivate the contractor to improve maintainability through the use of incentives, several issues arise that must be addressed. The first of these is a determination of what measures or elements of maintainability will be targeted for incentives. To be effective, the target must be defineable, measurable, demonstrable, and testable. Contractors interviewed expressed concern about the Government's ability to adequately determine these measures. Too often, they said, they received vague and incomplete specifications or work statements that made it very clear the Government did not know exactly what it wanted. Incentive targets must be explicit. For maintainability, the components chosen as targets must be hardware related and under the design control of the contractor. In addition, the target must be constructed as objectively as possible. If a formula is used to compute the value of the element, then all assumptions regarding the derivation of the formula, the definitions of terms used in the formula, and any circumstances that would result in adjustments to the value of those terms must be stipulated as part of the contractual instrument.

The interviews revealed that part of the problem of what to target is the source of the information concerning the targets. Government program personnel can offer suggestions based upon their view of the problem as can perspective contractors, but these sources will naturally bias their information in favor of their own parochial interests or abilities. The best sources of information on the maintainability requirements for a new system are the operating and maintenance personnel who will operate and maintain it. In the F/A-18 program, contractor personnel visited fleet units and talked to operating and maintenance personnel during concept exploration. This permitted them to become familiar with the operating and maintenance environment of the system before getting too heavily into the design of the aircraft. As a result the designers possessed a better understanding of the nature of the problem faced by the using units. The operating and maintenance personnel's viewpoint will also be biased. However, it will be biased in the direction of the realities of the environment in which the system must be used and not by design or engineering theory or the political issues that surround the program.

The target of the incentive should be a specific parameter and not some general measure of maintainability. For example, MTTR, MTBM, or MMH/OH are too general to be used by themselves and, as discussed earlier in the study, in the case of MTTR, many of the elements that comprise it are not controllable by hardware designers. If general measures are targeted then they should be used during the later portion of the program. For instance, to motivate the contractor during full scale development and production and deployment of the system, measures like MTTR and Ao may be more appropriate. Using incentives in these areas will help to stimulate the contractor's interest in shortening LDT, MDT, and ADT by ensuring that adequate supply support, training procedures, technical publications, and facilities are considered by program personnel. To motivate the contractor early in the program, the design related components of maintainability such as delay time, fault location time and its components, and adjustment and calibration time should be targeted. These components are very objective, measurable, and subject to design trade-offs. In considering what to target for maintainability incentives, targets that motivate the contractor over the duration of the acquisition process are more appropriate. During design and development of the system targets should be considered that are hardware specific and as objective as possible. During the later phases more general measures such as Ao and MTTR to help stimulate the contractor's interest in the other elements of maintainability should be used.

Several interviewees indicated that after deciding what parameters will be targeted for incentives, several issues remain unanswered. These concern primarily the demonstration and testing of the parameters chosen for incentive award. They include the method of testing of the hardware produced, the personnel conducting the test, the evaluation criteria for determining the success or failure of the contractor's effort, and who will make the determination that the contractor has earned the incentive. Answering these questions affords the Government the opportunity to motivate the contractors by involving them in the construction of the evaluation process. One method of accomplishing that task is to form a board of program and contractor personnel to collect and analyze the data from the testing of the system and prepare recommendations to be submitted to program management for determination of the success of the contractor's effort. Testing for incentive award purposes should be done by operating and maintenance personnel who will receive the system. The test should be conducted under the supervision of an independent testing facility. The testing personnel would also submit findings to the program manager regarding the success of the contractor's efforts. Testing should be done on full scale development and production models of the system. To win the incentive the contractor must demonstrate achievement of the targeted parameters on full scale development and production models of the system. It was pointed cut by some interviewees that by involving the contractor in the evaluation process, many of his concerns about the fairness of the evaluation criteria or testing methodology will be alleviated.

E. SUMMARY

This chapter analyzed the issues surrounding the appropriateness of using incentives for maintainability improvement. It also provided an analysis of the problems and issues involved in the construction of incentives for that purpose. The next chapter provides the conclusions, recommendations, and answers to the research questions formed in the study.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Based upon the findings by the researcher the conclusions for the study are contained in the following:

1. Incentives are appropriate for use in Government contracts as a method of motivating contractors to improve maintainability in weapon systems under design. Maintainability is composed of elements of sufficient objectivity to be appropriate targets for incentives. Chapter III, Section B described the components and identified the particular elements best suited for incentives. Chapter IV, Sections C and D discussed the issues involved in the structure of incentives as well as the significant characteristics which should be considered when attempting to use them to motivate a contractor to improve maintainability. Chapter V contains an example of the successful application of maintainability incentives in the F/A-18 program and discusses the factors that led to its success. Maintainability is described by many different measures and an effective incentive might be applied to any one of them. The F/A-18 program demonstrates that incentives targeted to maintainability can have a significant impact on the priority and level of attention given to it during design and development of the system. The incentives also help the Government to establish their maintainability objectives for the system and communicate these objectives to the contractor. The ultimate result of the incentives in the F/A-18 program was a

superbly maintainable aircraft that will provide better availability, lower operating and maintenance costs, and improved equipment readiness to the fleet. There is every reason to believe that this success can be duplicated in new weapon systems being acquired if incentives for maintainability are used.

2. The process of attempting to motivate the contractor to improve maintainability by means of incentives is not widely used today. The contractors interviewed indicated that maintainability specifications were present in most of the contracts they had, but incentives were not attached to them. They indicated the emphasis was still on the reliability of the system. As discussed in Chapter IV, Section D the reliance on merely a specified level of maintainability will not motivate the contractor to do more than comply with the specification. If contracting officers wish to induce the contractor to improve significantly above that level, maintainability must be given more priority and attention by Government acquisition managers. The F/A-18 represents the first system in NAVAIR to use an incentive program that included maintainability incentives as part of the contract and its success helped to demonstrate that maintainability was an appropriate target for incentives. Based upon the success enjoyed by the F/A-18 program and with continued interest in improved maintainability by program management, as prompted by users, incentives used for maintainability improvement will become more prevalent.

3. Maintainability is playing a greater role in the acquisition of equipment. The reliability and maintainability program for the F/A-18 program is an excellent example of the increasing role

maintainability as well as the other elements of ILS are playing in acquisitions today. Chapter II, Section A and Chapter VI, Section A described the increasing role of maintainability in the acquisition of weapon systems today. The theme of the "New Look" program at NAVAIR is that reliability and maintainability should be by design, not by chance.

4. <u>Maintainability has a definite impact on the life cycle cost of the system and must be considered from program initiation</u>. Maintainability is not a feature that can be added to a system just prior to production. Maintainability is a design feature subject to trade-offs against other design features such as reliability, cost, weight, and performance. Decisions to increase the maintainability of a system are made at the expense of other traits and must be done with the knowledge of the impact of those decisions.

5. <u>Maintainability objectives must be established early in the program and those objectives must be clearly communicated to industry, laboratories, or universities preparing the alternative concepts for the system</u>. As discussed in Chapter III, Section C and Chapter IV, Section F, maintainability objectives must be established early in the acquisition process and considered throughout. If incentives are to be used to achieve these objectives, the areas to be incentivized and how much money will be committed to the effort must be communicated to the concept designers early in their efforts.

6. <u>The role of maintainability will remain secondary to the reliability of a weapon system</u>. This will remain the case unless specific attention is directed to maintainability because of the pressure on the

contractor to have a fail-proof weapon system. Chapter III, Section D discussed the trade-offs involved in the design of a weapon system and pointed out that a direct trade-off exists between reliability and maintainability. It was established during interviews that contractors had more to lose designing a system that was unreliable than one that was just unmaintainable and would continue to direct their efforts toward system reliability at the expense of maintainability unless the Government directed otherwise.

7. <u>Different contractors are motivated by different incentives</u>. A corporation is a growing and maturing organization and some incentives that motivate it during its early years will not necessarily motivate it as the organization matures. To be effective, incentives must be tailored to fit the contractor's needs as well as the Government's objectives. In Chapter IV, Sections A and E, the significant characteristics of incentives and the factors that motivate contractors were discussed. The role of these characteristics was shown in Chapter V, Section C with the F/A-18 example and again in Chapter VI, Sections B and C in the description of factors to be considered in using incentives for maintainability.

8. <u>Only three of the eight components of maintainability are suitable for incentives</u>. Those components are delay time, fault location time, and adjustment and calibration time. The remaining five components are predominantly functions of the other elements of Integrated Logistics Support (ILS) and the reduction of the times in those components will be reflected by the ILS planning for the system. As discussed in Chapter III, Section B and Chapter IV, Section C,

these components are hardware related and are the most suitable for incentives because they ultimately drive the values for the cumulative measures such as Mean Time To Repair (MTTR), Maintenance Manhours/Operating Hour (MMH/OH), and Operational Availability (Ao). Further, using incentives targeted at those parameters will force the designer to consider Built in Test Equipment (BITE) and other design factors when designing the system.

9. The award fee contracting method of structuring incentives has the greatest potential for achieving maintainability goals. This was demonstrated in Chapter V, Section C in the F/A-18 example and again in Chapter VI, Section C in the discussion of the issues involved in structuring the incentive. To effectively motivate in this context the award fee structure requires a concise definition of the target of the incentive, the amount of the award to be earned, and the demonstration requirements for earning the award. The use of the award fee allows the contractor to make key decisions regarding the incentive by providing management with a valuation of the award.

B. RECOMMENDATIONS

Based upon the findings of the study and the conclusions derived from it, the researcher recommends the following:

1. The use of incentives to motivate contractors to design more maintainability into new weapon systems should be expanded beyond the current levels. Incentives have been shown to be an effective method of directing contractor attention to Government objectives in system acquisitions and, if

sufficiently rewarding, will induce the contractor to devote more effort toward accomplishing those objectives. Maintainability has been shown to be a significant driver in the operating and maintenance costs of a weapon system. It has demonstrated repeatedly its effect on the availability of the system and fleet readiness. Therefore, to help reduce the operating and maintenance costs and improve the availability and readiness of the equipment to be used in the fleet tomorrow, it is imperative that maintainability be a prime objective in the acquisition of systems under design today. Incentives are an effective means of ensuring that maintainability will receive the attention it warrants. Expanding the use of incentives for maintainability improvement could be encouraged if program managers were required to stipulate maintainability objectives and demonstrate maintainability growth in the systems they manage. This will require a commitment on the part of the Government and contractor personnel early in a program and will require continued attention to the Reliability and Maintainability implications of every decision in the program.

2. <u>An experiment on the maintainability characteristics of certain weapon systems should be conducted to determine which family of weapon systems are most appropriate for maintainability incentives</u>. Before meaningful incentives can be constructed for improved maintainability it is necessary to understand the peculiar maintainability characteristics for individual weapons families and whether maintainability is an appropriate incentive target. The experiment would involve the identification of the type of

weapon (eg., tank, missile, ship, aircraft, etc.), maintenance concept generally employed for the system, the operational mission of the system, and the degree of organizational maintenance required for the system. The experiment would help establish classes of weapons in which maintainability incentives are highly appropriate, appropriate, or not appropriate as a means of accomplishing program and operational objectives. It would also help to identify parameters most suitable for incentives. Establishing these classes would also assist in the development of a general model for structuring maintainability incentives. The buying commands should be tasked with performing such an experiment on all weapon systems under their purview and publishing the results in a guide appropriate for use by program managers.

3. <u>A generalized model for structuring maintainability incentives should be developed for families of weapon systems and applied in their acquisition on a case-by-case basis</u>. A generalized model would help to segregate the differing maintainability objectives that often exist between different weapon types and will help to identify the role of the maintenance concept in the formation of those objectives. For example, the maintainability objectives, characteristics, and maintenance concept for a tank are different than those of an attack aircraft and both will differ from those in a radar system. To structure the most effective maintainability incentives possible, these differences must be clearly identified and addressed. The buying commands could accomplish this by identifying maintainability objectives for all their system acquisitions in general terms

and then developing for each weapon family (eg. tank, aircraft, ship, etc.) those specific maintainability objectives they desired that system to possess. After identifying the family's maintainability objectives, they could be utilized to develop specific parameters to be available for use as a guide in developing incentive targets. As programs are initiated, the program managers would have a general guide to assist them in tailoring maintainability incentives to meet specified program, family, and customer maintainability objectives.

4. Incentives should be tailored to fit the needs of the contractor involved. Tailoring of incentives to contractor needs is important to ensure that an incentive designed to motivate a contractor in a particular part of a program, actually motivates him in that area. For instance, a contractor with a production contract that desperately needs the activity in the plant to remain open during a business slump between contracts is not going to be motivated by an incentive that encourages him to deliver earlier than the date specified in the agreement. Or consider an incentive that adds 3% more profit to the contract to reward design efforts in reducing the weight of a system, but costs the contractor 5% to pay for the effort. A contractor needing more profit at this particular time will not be motivated to pursue the incentive. However, a contractor that is attempting to build his reputation with DoD or his industry peers as an innovator or problem solver may take less profit on the instant contract to satisfy his need for prestige. The importance of understanding the contractor's business needs is to help make the incentives chosen more effective in

accomplishing Government objectives. Tailoring of incentives to contractor needs can be accomplished by requiring more analysis of the contractor's position in the industry prior to the construction of the incentive to ensure it has potential to motivate the contractor. It will also require flexibility on the part of Government contracting representatives to take the time to develop a suitable incentive arrangement.

5. <u>In incentive contracts for maintainability the use of award fees should be encouraged instead of the sharing formulas</u>. The award fee requires more definition in terms of target of the incentive and more money early in a system's life cycle, but is generally considered to be a more objective arrangement than the sharing formula. Additionally, the award fee provides several advantages in an incentive arrangement for maintainability that the share ratio cannot meet.

C. ANSWERS TO THE RESEARCH QUESTIONS

The answers to the primary and subsidiary research questions are provided in the following:

1. <u>The primary research question was: Can incentives be used in Government contracts to improve the maintainability of equipment acquired in the future</u>? The answer to the primary research question is clearly, yes. Incentives have been shown to be an effective method of directing contractor attention toward the maintainability characteristics of the equipment under design. The incentives used might take a variety of forms. They may be positive incentives focusing on such things as profit, multi-year

procurements, or capital investments. Negative incentives might also be used. These would concentrate on the contractor's fear of failing to perform as required by the contract. Some of the possible negative approaches might include maintainability warranties or extremely tight maintainability specifications.

2. <u>What is maintainability</u>? Maintainability is a characteristic of design and installation in a weapon system that makes it possible to meet operational objectives utilizing a minimum amount of maintenance resources.
3. <u>How does maintainability relate to the acquisition of equipment today</u>? Maintainability is a characteristic of design and as such must be considered at the initiation of the program. Maintainability is also subject to trade-offs with other design parameters such as reliability, weight, or performance. It must be considered when formulating system objectives and must be considered in subsequent design decisions.
4. <u>What motivates a contractor to do business with the Government today</u>? Defense contractors are motivated to do business with the Government for a variety of reasons. First, the defense business is relatively stable in spite of periodic changes in volume and intensity. Second, defense contractors perceive a vital need for their product today and in the future. Third, defense contractors do business with the Government for patriotic reasons and believe they make a significant contribution to the defense of this country. Finally, defense contractors believe that the business is very profitable and provides a respectable return on their investment.

5. What are the significant characteristics of contract incentives? Successful contract incentives generally possess the following characteristics: First, the incentive is designed as a positive motivator of contractor performance. It is used to encourage the contractor to extraordinary performance rather than penalizing the contractor for substandard performance. A second characteristic of an incentive is its recognition potential, that is, its ability to recognize the accomplishments of the contractor and his employees. Another characteristic of an incentive is the challenge it presents to the contractor involved. Challenging and realistic objectives and incentive targets are essential to direct contractor interest and innovation in the targeted areas. A fourth characteristic is the timeliness of the award of the incentive after demonstrated performance. The award should be paid when the target is achieved and not hidden in progress payments or in a contract settlement paid some time in the future. Finally, the incentive should motivate the contractor to perform. Understanding the motives of the contractors involved in the program is also necessary to develop successful incentives.
6. What would the objectives of incentives for maintainability be in Department of Defense contracts? The objectives of maintainability incentives in DoD contracts are: to reduce the life cycle costs of a new system, particularly with respect to the operating and maintenance costs of the system; (2) to improve the operational availability of newly acquired systems; (3) to improve the efficiency and effectiveness of the support efforts for the new system; (4) to improve the operational readiness of

the units in the fleet that receive the new systems; (5) to promote a team approach in the development of new systems; and (6) to encourage the contractor to achieve a higher level of performance than the minimum specifications for the system.

7. <u>What are the current methods used to promote maintainability in Government contracts</u>? Maintainability has not been a favorite target for incentives in Government contracts until recently. Most of the incentives in the areas of support have been directed toward the reliability of the system. The methodology in those efforts have varied from the use of award fees given to the contractor for meeting specified reliability goals to the use of warranties to guarantee the reliability of a system with the contractor being responsible for the costs of the unreliable systems. The F/A-18 program represents the first weapon system acquired by NAVAIR to target maintainability goals for incentive award in addition to the more traditional ones established under award fee type contracts.

8. <u>How can incentives be used to motivate the contractor to improve maintainability</u>? Incentives can be used to motivate the contractor to improve maintainability in new systems by focusing corporate management attention to the targets of the incentives, identifying Government's maintainability objectives in the system, and to reward the contractor for design efficiency and innovation.

D. AREAS FOR FURTHER RESEARCH

Additional research should be conducted in the following areas: (1) to determine if multi-year contracts would be an appropriate means and effective method of improving the maintainability of new weapons, and (2) to determine if capital investment incentives would be an effective or appropriate means of motivating the contractor to improve the maintainability of a system under design.

APPENDIX A

LIST OF PERSONNEL INTERVIEWED

1. Althaus, Walter F. Program Manager Ground/Surface Systems, ESL Corp. San Jose, California, Interview, August, 1984

2. Annett, Robert L. ILS Manager-MX, Westinghouse Electric, Corporation, San Mateo, California, Interview, September, 1984

3. Belcher, Kenneth A. Senior Engineer, Aerojet Strategic Corporation, Citrus Heights, California, Interview, September, 1984

4. Dellinger, Don, Mechanical Engineer, R&M Branch, U.S. Naval Air Systems Command, Washington D.C. Interview, August, 1984

5. Froleich, Gordon, Vice President for Contracts, California Microwave, San Jose, California, Interview, September, 1984

6. Glaser, John, Logistics Manager, Wright Patterson Air Force Base, Dayton, Ohio, Interview, September, 1984

7. Hobbs, J.C. Director, Contracts and Pricing, Teledyne Ryan Electronics, San Diego, California, Interview, August, 1984

8. Kearney, James F. Senior Systems Engineer, Grumman Aerospace Corporation, Mineola, New York, Interview, October, 1984

9. Kelly, Tom, Contracts Manager, Hughes Ground Systems Division, Pomona, California, Interview, August, 1984

10. McTeague, Mark, Major USMC, Integrated Logistics Support Coordinator, LMA Branch, Headquarters U.S. Marine Corps, Washington, D.C. Interview, October, 1984

11. Melnick, Eugene K. Maintainability Engineer, Boeing Aerospace Co. Bellevue, Washington, Interview, October, 1984

12. Peterson, Elmer L. B-1B ILS Manager, Rockwell International, Carson, California, Interview, October, 1984

13. Pliska, T.L. Assistant Manager, R&M Division, Hughes Ground Systems Division, Pomona, California, Interview, August, 1984

14. Quail, Stanton E. Logistics Manager, Ford Aerospace Communications, Sunnyvale, California, Interview, October, 1984

15. Sarri, Al, Manager R&M Division, Hughes Ground Systems Division, Pomona, California, Interview, August, 1984

APPENDIX B

INTERVIEW QUESTIONS

1. How do you view the logistic support issues when preparing or responding to a RFP or RFQ?

2. What role does maintainability play in a system you are designing and how are trade-off decisions made during the design?

3. What would motivate you to focus more design effort into the improvement of maintainability in systems under design today?

4. What do you consider to be the significant characteristics of an incentive in an incentive contract or similar arrangement?

5. Are incentives currently being used in any of your present defense contracts and what areas are being targeted for the incentive? If not, why?

6. Is the Government using incentives to encourage the improvement of maintainability in the design of future systems?

7. What is it that acts as the greatest incentive for your company in participating in defense contracts?

8. Where and what should the incentive be when attempting to improve the maintainability or other logistic support considerations in the new systems being acquired today?

9. How would you construct an incentive to improve the maintainability in a new acquisition today?

10. Do you think that improved maintainability can be accomplished through the use of incentives and if not, is there a more appropriate method to be used?

APPENDIX C

F/A-18 NON-ACCOUNTABLE LABOR DEFINITIONS

The following are definitions of non-accountable labor for the F/A-18 program: [Ref. 29]

1. The labor to rework any part drawn from supply to reestablish its useful life or pre-issue check.
2. Labor of removing, installing, checkout and testing involving the acquisition of parts through cannibalization. This applies only to the time spent on the cannibalized aircraft.
3. Maintenance induced damaged where technical data is not being followed.
4. The modification, rework, or adaptation of nonstandard parts to create a usable spare.
5. Maintenance performed as a result of operator error, or improper handling of equipment.
6. Look phase of inspections not defined in Maintenance Requirements Cards.
7. Maintenance actions for failures induced by equipment operation outside design envelope.
8. Maintenance actions for failures induced during maintenance when such actions could have been avoided if proper GSE were on hand.

The following are considered nonproductive types of effort and were excluded when determining required parameters:

1. Delivery of parts to close proximity of the aircraft.
2. Parts turn-in time.
3. Personal time (coffee breaks, etc.).
4. Researching manuals for the purpose of training personnel.
5. Delay of all types including weather.
6. Time spent proceeding to and from the scene of work.
7. Any interruption resulting from flight test type equipment, and special investigations which impede the normal maintenance process.
8. Forms documentation other than entry of direct, accountable maintenance actions/time upon the VIDS/MAF, or applicable CLEAR forms.
9. Non-active maintenance times to include cure times, battery charging times, and wait time after erasing Ultraviolet (UV) PROMS before reprogramming.

10. Repair time spent as a result of human error in not following approved technical manuals/maintenance procedures as determined on a case-by-case basis by the MDRB.

11. Validation or revision of technical data and similar tasks not related to required maintenance.

12. Movement of aircraft due to weather, disaster prevention, and practice exercises involving aircraft movement.

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